PARTICULATE FILTERS
AT THE
WABASH RIVER COAL GASIFICATION REPOWERING PROJECT

Advanced Coal-Based Power and Environmental Systems '98 Conference

Michael J. Hickey
Dynegy Power Corp.
444 W. Sandford Avenue
West Terre Haute, Indiana 47885

Thomas A. Lynch
Dynegy Power Corp.
444 W. Sandford Avenue
West Terre Haute, Indiana 47885

ABSTRACT

The Wabash River Coal Gasification Repowering Project (WRCGRP), a joint venture between Dynegy Power Corporation (formerly Destec Energy, Inc.) and PSI Energy, Inc., began commercial operation in November of 1995. The Project, selected by the United States Department of Energy (DOE) under the Clean Coal Program (Round IV) represents the largest operating coal gasification combined cycle plant in the world. This Demonstration Project has allowed PSI Energy to repower a 1950's vintage steam turbine and install a new syngas fired combustion turbine to provide 262 MW (net) of electricity in a clean, efficient manner in a commercial utility setting while utilizing locally mined high sulfur Indiana Bituminous coal. In doing so, the Project is also demonstrating some novel technology while advancing the commercialization of integrated coal gasification combined cycle technology.

A full commercial scale Hot/Dry Particulate Removal system was one of several technology improvements demonstrated at the Wabash River plant. Excellent progress has been made since startup in the development and testing of barrier filter element systems. Still, the barrier filter element system has been slow to achieve the same reliability status as compared to other components within the IGCC systems.

Large-scale testing of commercially available ceramic/metal barrier filter element systems has revealed several issues of concern relative to their use; including pore plugging, difficulty removing cake buildup on filter elements, metallurgy concerns, and element failure due to thermal/mechanical stresses.

In 1997, Dynegy received DOE funding to help support the design and construction of a Hot/Dry Particulate Removal slip stream unit at the Wabash River plant. The unit has been successfully commissioned and proven to be operationally sound. This paper will focus on the slip stream test plan objectives for advancing Dynegy's Hot/Dry Particulate Removal system technology.

INTRODUCTION

WRCGRP Overview

The Wabash River Coal Gasification Repowering Project (WRCGRP), a joint venture between Dynegy Power Corporation (formerly Destec Energy, Inc.) and PSI Energy, Inc., was selected by the United States Department of Energy (DOE) in Sept. of 1991 as a Round IV Clean Coal Technology demonstration project. The project represents the largest operating coal gasification combined cycle plant in the world today.

The Project utilizes Dynegy's gasification process integrated with a new General Electric 7 FA combustion turbine generator and a Foster Wheeler heat recovery steam generator (HRSG) to repower a 1950s-vintage Westinghouse steam turbine generator. The gasification facility processes 2544 tons/day of locally mined high sulfur Indiana Bituminous coal to produce 262 MW (net) of electricity in a clean efficient manner. The Project has a demonstrated heat rate of 8910 Btu/kWh (HHV) which is second highest in efficiency for all of CINergy's (PSI's parent company) generating plants behind their hydro-electric facilities. The Project site is located at PSI Energy's Wabash River Generating station in West Terre Haute, Indiana

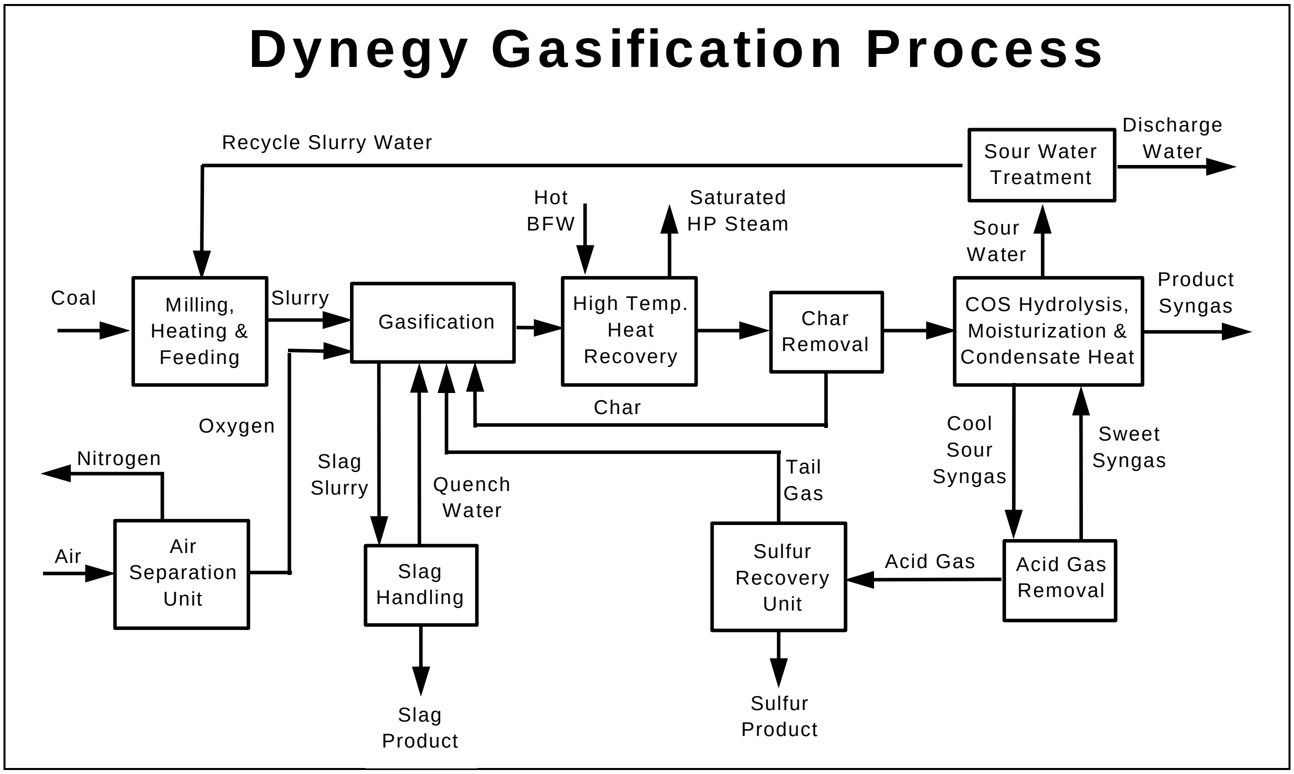
Goals of WRCGRP Participants

The goals of the participants within the Project are summarized as follows:

- PSI wants to demonstrate an alternative technology for new units and repowering of existing units. Also, PSI is incorporating this IGCC power plant into their system and wants to demonstrate this as a reliable and cost-effective element of their baseload generation capability.
- Dynegy is also demonstrating the operability, cost effectiveness and economic viability of its gasification technology in a commercial utility setting.
- Dynegy wants to further enhance its gasification technology's competitive position by demonstrating new techniques and process enhancements as well as substantiate performance expectations and capital and operating costs.

The DOE wants to abate the barriers to commercializing clean coal technologies, particularly gasification and repowering applications, and otherwise enable power generators to make informed commercial decisions concerning the utilization of clean coal technology.

WRCGRP General Design and Process Flow



The Dynegy coal gasification process features an oxygen-blown, continuous-slagging, two-stage, entrained-flow gasifier which uses natural gas for start-up. Coal is milled with water in a rodmill to form a slurry. The slurry is combined with oxygen in mixer nozzles and injected into the first stage of the gasifier, which operates at 2600°F and 400 psig. Oxygen of 95% purity is supplied by a turnkey, Air Liquide, 2,060-ton/day low-pressure cryogenic distillation facility which Dynegy owns and operates.

In the first stage, coal slurry undergoes a partial oxidation reaction at temperatures high enough to bring the coal's ash above its melting point. The fluid ash falls through a taphole at the bottom of the first stage into a water quench, forming an inert vitreous slag. The syngas then flows to the second stage, where additional coal slurry is injected. This coal is pyrolyzed in an endothermic reaction with the hot syngas to enhance syngas heating valve and to improve overall efficiency. The syngas exiting the second stage of the gasifier is laden with particulate consisting of unreacted coal and fly ash which is commonly referred to as char.

The syngas then flows to the high-temperature heat-recovery unit (HTHRU), essentially a firetube steam generator, to produce high-pressure saturated steam. This steam is exported to the power generation facility to be used in the steam turbine. After cooling in the HTHRU, particulates in the syngas are removed in a hot/dry filter and recycled to the gasifier where the carbon in the char is converted into syngas. The hot gas particulate removal system consists of two parallel configured filter vessels which utilize candle filtration technology. The char is periodically backpulsed from the candles utilizing high pressure recycle syngas. The char cake falls to the bottom of the vessel where it is transported back to the gasifier first stage. The 99.99% particulate free syngas exits the primary filter where it passes through a backup or secondary filtration system, and this system is likewise configured for two parallel gas paths. Filter-element construction and system configuration are proprietary designs that have evolved from full-scale testing at LGTI and improvements during the first two years of operation at Wabash. The syngas exiting the hot gas particulate removal system is further cooled in a series of heat exchangers, is water scrubbed for chlorides removal and is passed through a catalyst which hydrolyzes carbonyl sulfide into hydrogen sulfide. Hydrogen sulfide is removed using MDEA-based absorber/stripper columns. The "sweet" syngas is then moisturized, preheated, and piped over to the power block.

The key elements of the power block are the General Electric MS 7001 FA high-temperature combustion turbine/generator which has a 192 MW output when fired on syngas, the HRSG, and the repowered 104 MW Westinghouse steam turbine.

WRCGRP Production Summary and Operating History

Construction for the Project commenced in September 1993 and was completed by July 1995. After a three month period of commissioning, startup, and performance testing activities, commercial operation began in late November 1995. By March 1996 the plant demonstrated operation at better than design capacity reaching 103% of its nameplate syngas output. The project is currently in the third year of a three-year Demonstration Period under the DOE CCT program.

Table 1 summarizes gasifier and overall plant availability statistics from the beginning of the commercial operating period to the end of June 1998. The data illustrates that the 1996 commercial operating period was a challenging year. Although the gasifier availability was quite high at 87%, the overall plant was available only 27% of that time. Losses in overall plant availability were mostly attributable to problems in syngas path related processes, gasifier support systems, and in the combined cycle power generation facility. One of the most significant contributors to plant downtime in 1996 was the low availability of the hot gas particulate removal system. A number of fast track plant improvement projects were implemented that year which resulted in elevating plant availability in 1997 to 57%. Additional improvements installed in 1997 and early 1998 have further increased plant availability so that it is now approaching 75%, and continuing to increase to commercial competitive levels.

Table 1

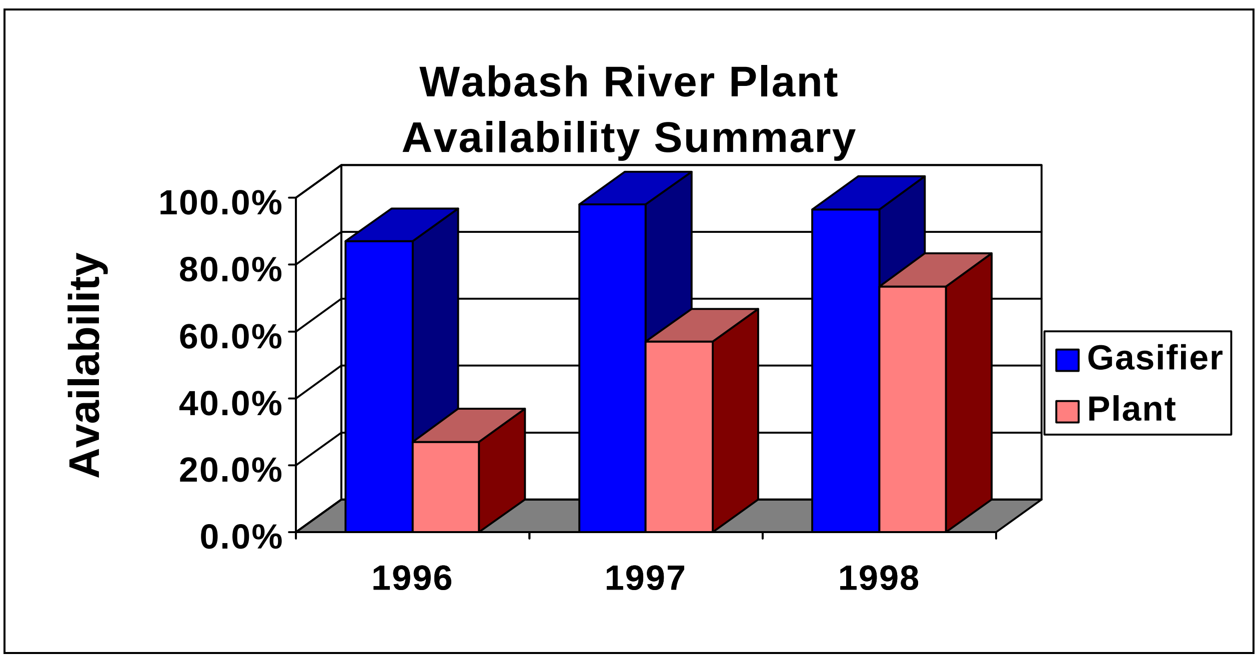
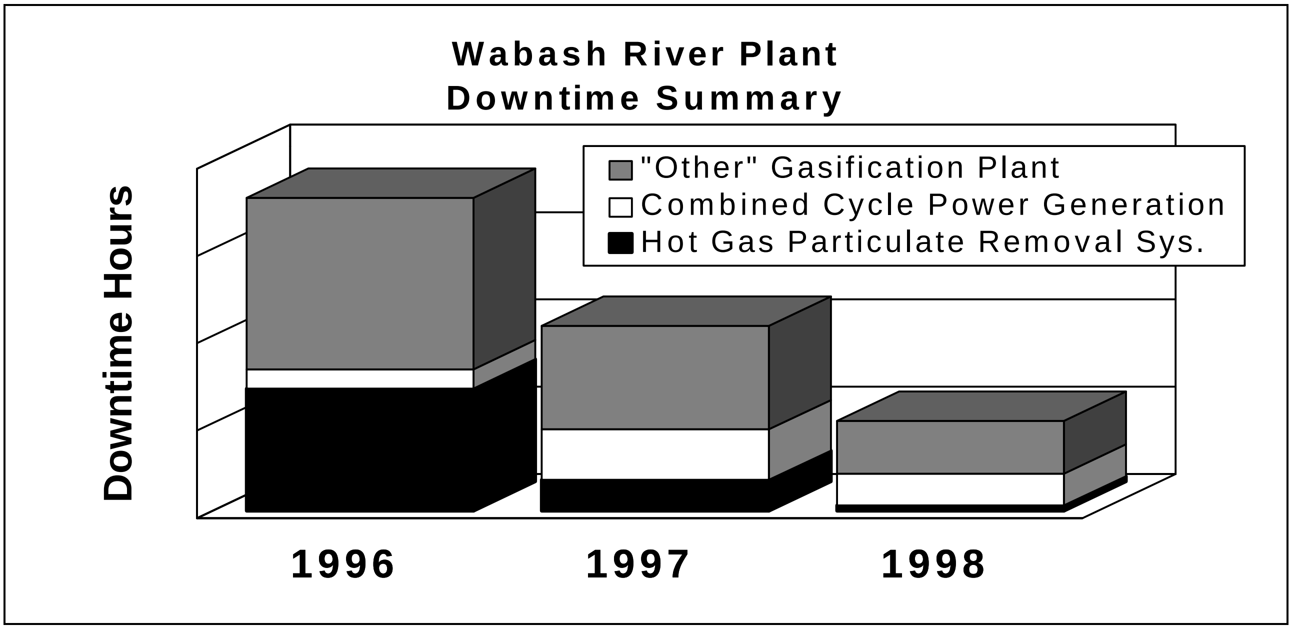


Table 2 illustrates the percentage of total downtime hours attributable to the hot gas filter system as well as plant outage hours caused by other gasification plant processes and the combined cycle power generation facility. In 1996 difficulties in the hot gas filtration system made up over 39% of the total plant downtime. As hot gas filter system improvements were implemented, its operation improved in 1997 with the total attributable downtime being reduced to around 17%. Additional improvements in 1997 and early 1998 have further reduced the hot gas filter system attributable downtime to below 6% of the total.

Table 2



During the 1995 - 1996 startup and commercial operating period, a number of hot gas filter system reliability problems were quickly identified and corrected. During the initial plant startup char was found breaking through the primary candle filter system. The source of this leakage was found to have occurred from gasket problems in both the element fixing hardware and filter modular tubesheet flange connections. These problems were easily resolved by changing gasket materials in the element fixing hardware system and by implementing a number of small changes in the modular tubesheet flange design. As run time accumulated more difficult challenges were realized as ceramic candle failure and bridging of solids between the filters began to occur.

The original design of the backpulse system yielded fairly low pressures when measured inside the candle filter during the backpulse event. It was soon realized that inadequate reverse flow during the backpulse event and resultant candle filter bridging occurred at fairly low primary hot gas filter forward flow differential pressures. Several components within the system were re-sized and implemented to rectify this problem.

Another source of candle bridging and breakage resulted from mixing filters of various flow resistances (or permeability) within the primary vessels. It was soon realized that installing a new cluster of filters in a vessel full of conditioned (or used) candles typically led to bridging and resultant ceramic candle breakage within that cluster. Ceramic candle breakage also occurred in the new filters due to the higher instantaneous face velocity that resulted immediately after the backpulse event. Filter conditioning periods during plant startups and changes in vessel candle loading practices were used to mitigate this problem.

The initial candle filter used in the Wabash hot gas filter was a ceramic clay-bonded SiC type. Frequent candle failures in 1996 caused at least 5 major plant outages. Candle breakage resulted from a number of sources such as bridging, improper handling, and filter fixing hardware problems. As a result, the system was retrofitted with metal candles late in 1996.

Another source of candle breakage and bridging was caused by inadequacies within the primary vessel internal gas/solids distribution system. High filter impingement velocities from gas exiting the internal gas distributor caused filter surface erosion and resultant candle blinding at certain locations. Filter permeability was totally lost in these high wear areas on the candle surface. High erosion rates on some distributor parts also yielded low component life. Several improvements were implemented to this system which has significantly improved its performance.

Resolution of the above mentioned challenges resulted in significantly improving the reliability of the Wabash hot gas filter system. However, there continues to be opportunities for improving the system in order to meet specific performance goals. A number of areas continue to be studied and improved. Accelerated filter blinding continues to be a concern and is an area of keen interest in the filter system development work. Certain types of candle filters display a much more rapid blinding rate (loss of permeability) than others when operated in the Dynegy process. Two factors have been found to contribute significantly to this phenomenon. They are vapor phase condensation of trace metals on the candle surface, and small particle penetration into the candle surface pore structure. The mechanism for how these two interact to blind the candle continues to be an area of intense study. Filter corrosion is also a concern when operating with metal candle filters, especially if higher sulfur coal feedstocks are used. There also remain some opportunities for improving the internal gas distribution system to further increase component life as well as minimizing filter surface gas impingement velocities.

OBJECTIVE

To position Dynegy’s gasification technology as a competitive and marketable process, the Wabash plant must meet its availability and O&M expenditure goals. Since the gasification process depends on the hot gas filter to be operating properly, it must be a highly reliable system. Specific performance goals have been established for the Wabash hot gas filter system. These goals, along with their current measurements, are shown in Table 3.

TABLE 3

Filter System Performance

Goal	Current Performance
No Lost Plant Availability	1997 17% Total Plant Downtime 1998 5.8% YTD Total Plant Downtime
10,000+ hr. Filter Life	5000 hr. Filter Life YTD
3300+ hrs. Between Filter Vessel Entries	1800 hrs. Between Filter Vessel Entries

Early on in the operation of the Wabash facility, it was realized that continued testing and development work would be required to improve the reliability of the hot gas filter system. It soon became apparent that it was not economically feasible to perform this work in the commercial scale vessels. Testing in the full scale vessels jeopardized plant availability and did not always yield meaningful data. For these reasons it was decided to implement a multi-element slipstream unit that could provide reliable data without risking plant availability.

Utilization of a slipstream test unit is better suited to test unproven filter types and system configurations without risking commercial scale system availability. It also provides more accurate blinding studies since the filters being tested have similar permeability. Previously blinding studies were conducted in the full scale vessel by installing new test elements in with used or conditioned filters. Consequently, the data often yielded somewhat questionable results. The slipstream unit also provides much needed data to be used in designing commercial scale hot gas filter systems designated for future gasification facilities. Data such as particulate loading, char characterization, and backpulse requirements for various types of feedstocks will be useful in designing alternate types of systems. By utilizing the slipstream system, process conditions can be altered and evaluations can be made to determine how they effect filter performance. Performing these studies on a smaller scale is a much more cost effective approach.

PROJECT DESCRIPTION

In 1996 Dynegy decided to engineer and implement a slipstream unit capable of performing the development work necessary to enhance the reliability and lower the O&M costs for the Wabash hot gas filter system. In 1997, the U. S. Dept. of Energy provided funding to help support the design and construction of the Wabash hot gas filter slipstream system

When designing the hot gas filter slipstream system specific criteria was established to ensure it would have maximum flexibility for testing alternate filters and system configurations as well to provide valid relevant data. To develop this criteria, a comprehensive list detailing what could be studied in the slipstream unit was generated. Included in this list were the specific studies required to increase the commercial scale system reliability and development work needed for application in future commercial systems. The design criteria established for the slipstream system is as follows:

- Design into the system the capability to test various filter types (candles, honeycomb, etc.), lengths, hardware configurations, and alternative system arrangements such as a multi-tiered design.
- The slipstream system should be designed to test multiple filters in a similar cluster type arrangement as is used in the commercial scale vessels.
- The slipstream system should fully simulate process conditions in the commercial scale vessels such as gas composition, gas pressure, gas temperature, solids loading, filter face velocities, backpulse conditions, and char recycle capabilities.
- The system must be capable of performing re-entrainment studies so that alternate configurations for internal gas distribution can be studied.
- The slipstream system must be capable of testing various types of secondary or backup filtration systems.
- Flexibility must be built into the system so that backpulse optimization studies can be performed.

The process design package for the Wabash Hot Gas Filter Slipstream project was generated by the Dynegy Engineering group during the first and second quarter of 1996. The detailed design engineering was performed by the Dow Chemical Engineering and Construction group in Houston, Texas. This effort was kicked off in late-May of 1996 and was completed by the middle of the 3rd quarter of that same year. The material and procurement phase for the project was initiated in the late phases of the detailed design and was completed by mid-second quarter of 1997. Field construction was kicked off in late April 1997 and completed by August of that same year. Commissioning and startup activities followed and the system came on line in November 1997.

APPROACH

The Wabash hot gas filter slipstream test program was developed to meet a specific list of objectives which focused on ways to improve the operation of the commercial scale unit in order to meet the goals set forth for that system. Test objectives not only focused on improving system operation but also to support the development of future commercial hot gas filter systems. Some of the test program objectives are described as follows:

- Test various types of filter constructions and measure the blinding rate when operated in the Wabash process. Use this data along with SEM/EDAX analysis to better understand what mechanisms cause accelerated filter blinding. Utilize experts in the field of coal combustion ash deposition to help determine mechanisms of filter blinding.

- Determine the optimum filter element to use in the Dynegy process.

- Determine the effect on filter performance when altering certain process conditions such as particulate filter gas inlet temperatures, backpulse conditions, and particle size distribution.

- Perform studies to accurately measure dust loading to the commercial scale hot gas filter system. These studies should be performed for the various types of feedstocks to be gasified such as petroleum coke and alternate coal sources. This data will be useful for validating plant process models.

- Perform studies geared toward better understanding the mechanisms that cause ceramic candle breakage. Test alternate hardware configurations that may improve ceramic candle reliability.

- Evaluate alternate primary and backup filtration systems such as a multi-tiered configuration (primary).

- Perform studies to determine minimum gas impingement velocities on candle filter surfaces. This information will be useful in designing internal gas distributor systems. Re-entrainment studies with alternate distributor system configurations will also be considered.

- Establish design criteria for future hot gas particulate systems by performing backpulse optimization and char characterization studies.

RESULTS AND FUTURE ACTIVITIES

Utilizing the above listed objectives and considering overall plant development requirements a comprehensive test program was developed. The first battery of tests which were conducted late last year, and early 1998, consisted of isokinetically measuring the dust loading to the commercial scale vessels. This data was collected for different types of gasifier feedstocks. Char characterization studies were also performed on each type of char. The slipstream system is currently being used to conduct a series of filter blinding studies utilizing ceramic and metal candle filters from various manufacturers. This study will help determine filter life in the commercial scale vessels when considering limitations due to on-line permeability losses. Alternate filter types and constructions are also being looked at during this study. Dynegy has been working with a number of of filter manufacturers to develop a candle that is best suited for the Wabash process. A number of these filters are slated for testing in the near future. Testing will also be conducted to complete a series of filter pre-conditioning studies. Evaluations will also be made on filter performance while varying a number of process conditions such as changing filter vessel operating gas temperatures and backpulse conditions. Backpulse temperature, duration, gas pressure , and sequential timing are some of the process variables being considered for this study. Backup or secondary filter testing with certain types of systems such as fail-safe devices are currently being evaluated. Alternate system configurations such as a multi-tiered arrangement is also slated for future testing.

BENEFITS

To date, the hot gas filter slipstream system has provided solids loading and char characterization data which has proven useful in validating plant process models for several types of gasifier feedstocks. This information is beneficial for preparing the gasification system to operate on alternate types of feedstocks. A number of filter blinding studies have also been conducted and results have been used to provide direction in selecting the best filter type for the Dynegy process employed at Wabash. This study is likely to continue through the end of 1998. Blinding mechanisms for the various types of filters are currently being evaluated. This data should provide insight concerning what process conditions, if any, may positively influence filter life due to blinding. Corrosion studies also continue for metal candles operated both in the slipstream and commercial scale units. This information will be useful in determining life due to corrosion related limitations.

Overall, the data being generated has been, and continues to be, quite useful in making decisions to improve the operation of the Wabash commercial scale hot gas filtration system. The information from these studies will ultimately lead Dynegy Power Corp. to develop a hot gas filtration system which is the lowest cost to operate and provide 100% reliability for the gasification process.